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(54) [Title of the Invention] MICROWAVE DISCHARGE LIGHT SOURCE

(57) [Abstract]
[Object] To improve starting characteristics and light-emitting efficiency of a microwave discharge light source due to more efficient supply of microwave energy to the interior of a discharge tube.

[Structure] Starting characteristics and microwave energy supply efficiency are improved due to the fact that a discharge tube 11 and a resonator 12 that incorporates in one conductive material a functional part that possesses electromagnetic induction properties and a functional part that possesses electrical capacitive properties are located in a microwave resonant cavity and are arranged so that the electromagnetic energy is coupled with a filler that fills the interior of the discharge tube.

[Claims]
[Claim 1] A microwave discharge light source comprising: a generator unit that generates microwaves; a functional part that transmits the aforementioned microwaves;

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a power port; a microwave resonance cavity; a resonator that combines in one conductive member a functional part that holds electromagnetic inductive properties and a functional unit that holds electric capacitive properties; and a discharge tube that comprises a filler and a enclosure with light-transmitting characteristics, wherein said filler fills the aforementioned enclosure, said microwave discharge light source being characterized by the fact that the structure, which incorporates the discharge tube and the resonator that are arranged so that the electromagnetic energy is coupled with said filler, operates so that the functional part that holds the electromagnetic inductive properties of the resonator is activated by the resonance electromagnetic field inside the microwave resonance cavity and so that microwave energy can be supplied from said resonator to the discharge tube.

[Claim 2] The microwave discharge light source of Claim 1, wherein said resonator has a construction of a loop-gap type resonator that comprises a resonance ring made of a conductive material and having an essentially cylindrical shape and at least one gap formed in the direction of the central axis of said resonance ring so that the electromagnetic energy can be coupled with said filler; the structure where said discharge tube approaches the edge of the loop-gap resonator and passes along at least a part of the central axis of said loop-gap resonator is arranged so that the magnetic field lines of the microwave cavity in the inner part of the microwave cavity generator are oriented substantially parallel to the central axis of the loop-gap resonator and so that microwave energy can be supplied from said resonator to the discharge tube.

[Claim 3] The microwave discharge light source of Claim 1, wherein said resonator has the construction of a loop-gap type resonator that comprises a resonance ring made of a conductive material and has an essentially cylindrical shape and at least one gap formed in the direction of the central axis of said resonance ring so that the electromagnetic energy can be coupled with said filler; the structure wherein at least a part of said discharge tube is inserted into the space inside the resonance ring of the loop-gap resonator being arranged so that the magnetic field lines of the microwave cavity in the inner part of the microwave cavity generator are oriented substantially parallel to the central axis of the loop-gap resonator so that the microwave energy can be supplied from said resonator to the discharge tube.

[Claim 4] The microwave discharge light source of Claim 1, wherein said resonator has the construction of a loop-gap type resonator that comprises a resonance ring made of a conductive material and has an essentially cylindrical shape and at least one gap formed in the direction of the central axis of said resonance ring so that the electromagnetic energy can be coupled with said filler; the structure wherein said resonator has at least two loop-gap resonator units and at least one discharge tube and wherein at least a part of the axis of said discharge tube and said central axis of the loop-gap resonator mutually coincide is arranged so that the magnetic field lines of the microwave cavity in the inner part of the microwave cavity generator are oriented substantially parallel to the central axis of the loop-gap resonator and so that the microwave energy can be supplied from said loop-gap resonator to the discharge tube.

[Claim 5] A microwave discharge light source comprising: a generator unit that generates microwaves; a functional part that transmits the aforementioned microwaves; a power port; a resonator that combines in one conductive member a functional part that holds electromagnetic inductive properties and a functional part that holds electric

capacitive properties; and a discharge tube that comprises a filler and a enclosure with light-transmitting characteristics, wherein said filler fills the aforementioned enclosure, said microwave discharge light source being characterized by the fact that said resonator and said discharge tube are arranged so that the functional part that holds the electromagnetic inductive properties of the resonator is caused to operate under the effect of the resonance electromagnetic field, whereby microwave energy can be supplied from said loop-gap resonator to the discharge tube.

[Claim 6] The microwave discharge light source of Claim 1, wherein said resonator has a construction of a loop-gap type resonator that comprises a resonance ring made of a conductive material and has an essentially cylindrical shape and at least one gap formed in the direction of the central axis of said resonance ring so that electromagnetic energy can be coupled with said filler; the structure where said discharge tube approaches the edge of the loop-gap resonator and passes along at least a part of the central axis of said loop-gap resonator is arranged so that magnetic field lines of the resonance electromagnetic field propagated through said power supply port are oriented substantially parallel to the central axis of said loop-gap resonator, whereby microwave energy can be supplied from said loop-gap resonator to the discharge tube.

[Claim 7] The microwave discharge light source of Claim 5, wherein said resonator comprises: a construction of a loop-gap type resonator that comprises a resonance ring made of a conductive material and has an essentially cylindrical shape and at least one gap formed in the direction of the central axis of said resonance ring; and a discharge tube having a light-permeable enclosure and a filler inside said enclosure; the structure in which at least a part of said discharge tube is inserted into the space inside the resonance ring of the loop-gap resonator being arranged so that the electromagnetic energy is coupled with said filler and so that the magnetic field lines of the resonance electromagnetic field transmitted through said power supply port are oriented substantially parallel to the central axis of the loop-gap resonator so that microwave energy can be supplied from said resonator to the discharge tube.

[Claim 8] The microwave discharge light source of Claim 5, wherein said resonator has a construction of a loop-gap type resonator that comprises a resonance ring made of a conductive material and has an essentially cylindrical shape and at least one gap formed in the direction of the central axis of said resonance ring so that the electromagnetic energy can be coupled with said filler; the structure wherein said resonator has at least two loop-gap resonator units and at least one discharge tube and wherein at least a part of the axis of said discharge tube and said central axis of the loop-gap resonator mutually coincide is arranged so that the magnetic field lines of the resonance electromagnetic field transmitted through said power supply port are oriented substantially parallel to the central axis of the loop-gap resonator so that microwave energy can be supplied from said resonator to the discharge tube.

[Detailed Description of the Invention]
[0001]
[Field of the Invention] The present invention relates to a microwave discharge light source of high-output luminous power.

[0002]
[Description of the Prior Art]
Light sources that use plasma-emitted light generated by a discharge lamp under the effect of microwave energy have been proposed and find practical application. In particular, it is expected that electrodeless discharge lamps, which are free of discharge electrodes and of a deterioration phenomenon caused by consumption of electrodes, will have a longer service life and will possess many other advantages over lamps with discharge electrodes. Therefore, in recent years attention is drawn to the aforementioned electrodeless discharge lamps as light sources of high power.

[0003] An example of a microwave discharge light source which is described in Japanese Unexamined Patent Application Publication (Kokai) JP61-99264A is shown in Fig. 9. In this drawing, reference numeral 91 designates a magnetron for generating microwaves, 92 designates a magnetron antenna, 93 is a waveguide, one end of which accommodates the aforementioned magnetron, 95 is a microwave resonance cavity, 96 designates a cavity wall connected to the other end of the waveguide 93, and 97 designates a light-transmitting element. Reference numeral 98 designates a power supply port which is provided in the cavity wall 96 and is used for feeding microwave energy into the microwave resonance cavity 95 through the waveguide 93. Reference numeral 99 designates a discharge tube that has a light-transmitting enclosure, is located inside the microwave resonance cavity 95, is made from a quartz glass, and is filled with rare gas, mercury, or another appropriate filler. Reference numeral 94 designates a reflection plate that reflects light emitted from the microwave resonance cavity 95 [a typo in the original where 75 is used instead of 95 – translator's note].

[0004] The above-described device operates as follows. Via the magnetron antenna 92, microwave energy generated by the magnetron 91is propagated to the waveguide in the transmission mode. Through the power supply port 98, microwave energy is supplied to the microwave resonance cavity 95. The transmitted microwave energy excites the discharge tube, causes evaporation of the aforementioned filler, and thus causes emission of light. It can be seen that in the above-described conventional microwave discharge light source the only unit of the light source that has a resonance function section is the microwave resonance cavity.

[0005]
[Problems to be Solved by the Present invention] However, the method used in the above-described conventional apparatus for feeding the power from the microwave resonance cavity 95 to the discharge tube 99 makes it difficult to initiate the light source. The reason for this is that prior to initiation of the source, ionization inside the discharge tube does not progress, the electrons and ions have low density, and a conductive pass is absent. In other words, it is difficult to start the light source because there is no concentration of microwave energy in the discharge tube. Another problem results from the fact that once the discharge is started, microwave energy is not supplied to the interior of discharge tube located in the microwave resonance field but rather dissipates and is lost whereby luminous efficiency for the supply capability decreases. Furthermore, since the wavelength of 2.45 GHz is about 12 cm, the minimal dimensions of the microwave resonant cavity 95 are limited to about several tens cm.

[0006] It is the first object of the present invention to eliminate the above disadvantages of the prior-art technique and to improve startability and light-generation efficiency by efficiently feeding the microwave energy propagated through the waveguide to the

interior of the discharge tube. It is the second object of the invention to reduce the dimensions of the portion of the resonance function part that extends from the power supply port.

[0007]
[Means for the Solution of the Problem] The above object is achieved by means of the present invention that provides a microwave discharge light source comprising: a generator unit that generates microwaves; a functional part that transmits the aforementioned microwaves; a power port; a microwave resonance cavity; a resonator that combines in one conductive member a functional part that holds electromagnetic inductive properties and a functional unit that holds electric capacitive properties; and a discharge tube that comprises a filler and an enclosure with light-transmitting characteristics, wherein the filler fills the aforementioned enclosure, the microwave discharge light source being characterized by the fact that the structure, which incorporates the discharge tube and the resonator that are arranged so that the electromagnetic energy is coupled with the filler, operates so that the functional part that holds the electromagnetic inductive properties of the resonator is activated by the resonance electromagnetic field inside the microwave resonance cavity and so that microwave energy could be supplied from the resonator to the discharge tube.

[0008] According to another aspect of the invention, the light source structure comprises: a generator unit that generates microwaves; a functional part that transmits the aforementioned microwaves; a power port; a resonator that combines in one conductive member a functional part that holds electromagnetic inductive properties and a functional part that holds electric capacitive properties; and a discharge tube that comprises a filler and a enclosure with light-transmitting characteristics, wherein the filler fills the aforementioned enclosure, the microwave discharge light source being characterized by the fact,that the resonator and the discharge tube are arranged so that the functional part that holds the electromagnetic inductive properties of the resonator is caused to operate under the effect of the resonance electromagnetic field, whereby microwave energy can be supplied from the loop-gap resonator to the discharge tube.

[0009]
[Function] By arranging the aforementioned resonator inside the microwave resonance cavity, it becomes possible to concentrate the resonance magnetic field generated in the inner part of the cavity on the periphery of the resonator and thus to electromagnetically couple the concentrated magnetic field with the discharge tube and hence to improve efficiency in the use of the supplied microwave energy.

[0010] Moreover, since the resonator may have a design smaller than the microwave resonance cavity, it becomes possible to miniaturize the part that fulfills the microwave resonance function of the light-emitting source by replacing the [existing] microwave resonance cavity and its resonator.

[0011]
[Practical Examples]
(Practical Example 1) The first example of the invention will now be described in more detail with reference to the accompanying drawings. Fig. 1 is a sectional view of the essential part of the microwave light source made in accordance with the first modification of the invention. A structure composed of a discharge tube 11 and a resonator 12 made from an electrically conductive material is located in a microwave

discharge light source, which, as a conventional source of this type, consists of a magnetron 13 that constitutes a microwave generation part, a waveguide 14 that constitutes a microwave propagation part, a power supply port 15, a microwave resonance cavity 17 made from a metal mesh, and a reflection plate 16. In the illustrated modification, the resonator 12 is used as a loop-gap resonator.

[0012] Operation and configuration of the loop-gap resonator will now be explained with reference to Figs. 7 and 8, wherein Fig. 7(a) is a cross-sectional view of the loop-gap resonator, and Fig. 7(b) is a three-dimensional view of the latter. As can be seen from these drawings, the resonator comprises a resonance ring of a cylindrical shape made from an electrically conductive material that has a gap of a predetermined width that is cut through the resonance ring in the direction [parallel to the] central axis of the resonator. When the direction of the central axis of the loop-gap resonator is arranged so that it becomes essentially parallel to the direction of the magnetic flux of the fluctuating electromagnetic field, the aforementioned cylindrical resonance ring acquires the properties of electromagnetic inductance, and a spiral inductive potential is generated in the circumferential direction. As a result, an electric field that possesses electrical capacitance is induced in the aforementioned gap. Fig. 7(c) shows an equivalent electrical circuit of the aforementioned loop-gap resonator. It can be seen that the resonance circuit consists of an inductor L, a resistor R, and a capacitor C. The greater is the resistance of the resistor R of the resonance circuit, the higher are the thermal losses in the resonance circuit. Therefore, it is desirable to make the loop-gap resonator from a conductive material with low inherent resistance in order to diminish the value of resistance in the equivalent circuit. Although for the device of the present modification copper is an acceptable material, the use of aluminum or silver is more preferable.

[0013] As shown in Fig. 7(a), the cylindrical resonance ring is characterized by the following dimensions: an inner diameter "r" of the ring; a wall thickness "W"; an axial length "Z"; and a width of the gap "t". If the number of gaps is "n", the dielectric constant is "ε" and if the magnetic permeability of vacuum is μ_0, then a relationship between the inductance L and capacitance C of the equivalent circuit of Fig. 7(c) can be expressed by the following group of formulae 1:

[0014]
[Group of Formulae 1]

$$L = \frac{\mu_0 \pi r^2}{Z}, \quad C = \frac{\varepsilon W Z}{tn}$$

[0015] The above formulae can be used for obtaining an approximate value of resonance frequency of the aforementioned loop-gap resonator by means of the below-given formula 2:

[0016]
[Formula 2]

$$2\pi\nu = \frac{1}{(LC)^{1/2}} = \frac{(tn)^{1/2}}{r(W\pi\varepsilon\mu_0)^{1/2}}$$

[0017] Thus, with a certain approximation, it can be stated that the length Z of the aforementioned cylindrical ring in the axial direction is not related to the resonance frequency.

[0018] In microwave discharge light equipment, resonance frequency is a fixed value and is determined by oscillation frequency of a magnetron. The generally used oscillation is 2.45 GHz. By inserting this value into the aforementioned formula that expresses the oscillation frequency ν, it is possible to define various dimensions of the loop-gap resonator. Since the device of the present modification has only one gap ($n = 1$), the inner diameter "r" of the cylindrical resonance ring will be equal to 1.5 cm. The relationship between the wall thickness W of the cylindrical resonance ring and the width of the gap "t" can be determined from formula 2 as follows: $t = 0.02\ W$. In other words, the dimensions of the aforementioned loop-gap resonator have a significant degree of freedom, and if one of such geometrical parameters as W (wall thickness of the cylindrical resonance ring), "r" (inner diameter of the cylindrical resonance ring), and "t" (width of the gap) is determined, the formula for the remaining two dimensions can be easily established and can be used to determine approximate dimensions of the loop-gap resonator as a whole.

[0019] As far as the cross-section of the loop portion is concerned for the device of the present modification, the most efficient results will correspond to a concentric circular shape since such shape provides the shortest path of current when induced current flows through the resonator. However, as long as the interior becomes a cavity and fluctuating magnetic flux passes through this cavity, a polygon cross-section, or the like, also will be acceptable.

[0020] Fig. 8 shows an example of variations in distribution of the magnetic field when the loop-gap resonator is installed inside the microwave resonance cavity. Reference numerals 82a and 82b designate a microwave resonance cavity operating in the TE_{102} mode; reference numerals 83a and 83b show distribution of magnetic force lines of a strong magnetic field inside the microwave resonance cavity of the aforementioned TE_{102} mode, and reference numeral 81 shows a loop-gap resonator that has the same resonance frequency as that of the microwave resonance cavity of the aforementioned TE_{102} mode.
As compared to the magnetic field distribution for the conventional TE_{102} mode shown in Fig. 8a, the device that contains the loop-gap resonator 81 arranged inside the microwave resonance cavity so that the magnetic field lines in the aforementioned cavity are substantially parallel to the central axis of the loop-gap resonator provides magnetic field distribution with concentration of magnetic field lines inside the loop-gap resonator part, as shown in Fig. 8b.

[0021] The structure of the discharge tube and the loop-gap resonator in the device of the first modification is shown in Fig. 3. In this drawing, reference numeral 31 designates a discharge tube that comprises a spherical enclosure made from quartz glass that has a diameter of 30 mm and is filled with a filler such as argon gas (5hPa) and 20 mg of mercury; reference numeral 32 designates a loop-gap resonator that is made from copper and has one gap arranged parallel to the central axis of the cylindrical body of the resonator. Various dimensions of this resonator were determined on the basis of the above formula for the inner diameter of the cylinder equal to 1.5 cm. The discharge tube 31 is arranged so that the central axes of the discharge tube 31 and of the loop-gap resonator 32 mutually coincide near the edges of the resonator 31.

[0022] For the loop-gap resonator 32 of the type shown in Fig. 3, the magnetic field lines will have the pattern shown in Fig. 3 by broken lines, but in positions outward from the edge of the loop-gap resonator 32, the magnetic field created by the resonance microwaves of the loop-gap resonator rapidly decreases. Therefore, it is desirable to arrange the resonator tube 31 as close as possible to the edge of the loop-gap resonator 32. However, when the discharge tube 31 is arranged so that it is nearly in contact with the edge of the loop-gap resonator 32, this may damage the resonator tube because the coefficient of linear expansion of the copper, which is the material of the loop-gap resonator 32, is equal to 0.175 at 300°C, and this significantly differs from the coefficient of linear thermal expansion of the quartz glass, which is the material of the discharge tube 31 and which at a temperature below 1000°C has a coefficient of linear thermal expansion equal to 5.5×10^{-7}. Therefore, clearance between the discharge tube 31 and the edge of the loop-gap resonator 32 should be sufficient in order to prevent interference between the parts when during operation the discharge tube 31 undergoes thermal expansion.

[0023] Fig. 4 illustrates the second modification of the discharge tube and the loop-gap resonator. In this modification, a discharge tube 41 that comprises a spherical enclosure made from quartz glass which has a diameter of 25 mm and is filled with gaseous argon (5hPa) and 12 mg of mercury is arranged inside the cylindrical ring of the loop-gap resonator 42 which is made of copper and has one gap [parallel] to the central axis of the cylindrical body of the resonator so that the central axes of the discharge tube 41 and of the loop-gap resonator 42 mutually coincide in the inner part of the cylindrical ring.

[0024] The loop-gap resonator of the second modification has the same dimensions as those of the first modification. In other words, the inner diameter "r" of the cylindrical resonance ring is set equal to 1.5 cm so that the resonator can operate at a frequency of 2.45 GHz and can satisfy the relationship t = 0.02 W between the gap width "t" and the thickness W of the cylindrical resonance ring. Furthermore, in order to allow light generated by the discharge tube 41 to emit to the outside of the loop-gap resonator 42, the length Z of the cylindrical resonance ring is designed to be shorter than the length of the cylindrical resonance ring in the first modification.

[0025] As shown in Fig. 4 by broken lines, the intensity of the resonance magnetic field generated by the loop-gap resonator 42 is maximal in the inner part of the cylindrical ring of the loop-gap resonator 42. Therefore, when, as shown in Fig. 4, the discharge tube 41 is placed into the inner part of the loop-gap resonator 42, the efficiency of microwave energy supplied from the loop-gap resonator 42 to the discharge tube 41 will be higher than in the case of Fig. 3 with the discharge tube arranged outside the edge of the loop-gap resonator 42.

[0026] The closer the outer diameter of the discharge tube 41 is to the inner diameter of the cylindrical ring of the loop-gap resonator 42, the higher is the efficiency of the device, but taking into account the difference between the coefficients of thermal expansion of the copper and quartz glass, similar to the device of the first modification, some gap must be provided between the discharge tube and the loop-gap resonator in order to prevent interference that may be caused between these components due to heating.

[0027] As compared to other modifications, construction of the second modification provides maximum protection from light emitted by the loop-gap resonator. This makes it possible to exclude the use of materials not permeable to light, such as copper, for manufacturing the loop-gap resonator and, instead, to use a light-permeable dielectric material such as quartz glass with vapor deposition of a light-transmitting electrically conductive film of ITO, or the like.

[0028] Fig. 5 illustrates the third modification of the discharge tube and the loop-gap resonator. The device has a sealed discharge tube 51, which has a diameter of 30 mm and comprises a spherical enclosure of quartz glass filled gaseous argon (5hPa) and 20 mg of mercury. The discharge tube 51 is arranged so that it is located near the edge of the loop-gap resonator 52 which is made of copper and has two gaps extending in the actual direction of the cylindrical body. In the aforementioned third modification, both gaps of the loop-gap resonator are arranged symmetrically with respect to the central axis. The creation of two gaps means that the functional part of the device that during operation possesses electric capacitance of the loop-gap resonator is doubled so that the part that forms the resonance electric field will be doubled as well. Thus, as compared with the first modification, it becomes possible to distribute the microwave resonance electromagnetic field more uniformly between the inner part of the loop-gap resonator and the circumference of the latter. Furthermore, it becomes possible to provide more uniform conditions for light-generating plasma in the interior of the discharge tube.

[0029] The relationship between various dimensions and resonance frequency ν of the loop-gap resonator of this modification can be derived if n equals 2. Since resonance frequency ν is 2.45 GHz, the following relationship can be written for the gap width "t" of the loop-gap resonator 52 and the wall depth W of the cylindrical resonance ring when inner diameter "r" of the cylindrical resonance ring of the loop-gap resonator 52 is equal to 1.5 cm:

$$t = 0.01\ W$$

In the above modification, the number "n" of gaps is 2, but, in fact, the number of gaps may depend only on the type of equipment and machining operations, but, in general, the greater the number of gaps, the more uniform is the distribution of the electromagnetic field inside the loop-gap resonator.

[0030] Fig. 6 illustrates the fourth modification of the invention. The device comprises two loop-gap resonators 62 and 63, each made from copper in the form of cylindrical bodies with one gap in the direction parallel to the central axis of the cylindrical body. A sealed discharge tube 61 that comprises a 30 mm-diameter spherical enclosure made from quartz glass, which is filled with gaseous argon (5hPa) and 20 mg of mercury, is arranged between both loop-gap resonators 62 and 63. The geometric characteristics of the loop-gap resonators 62 and 63 are the same as those in the first modification.

[0031] The aforementioned pair of loop-gap resonators 62 and 63 is arranged so as to provide a mode of electromagnetic fields linked as shown in Fig. 6 so that the electromagnetic fields are concentrated between both resonators without dissipation. By arranging the discharge tube 61 between both resonators, it becomes possible to reduce dissipation and the amount of energy lost as compared with the first modification. In this

arrangement, however, due attention must be paid to the fact that light should emanate only from the gap between the resonators.

[0032] Since in all modifications of the discharge tube and the loop-gap resonator from the first to the fourth, which are shown in Figs. 3 to 6, the magnetic flux that is generated by the intrinsic mode in the interior of the microwave resonance cavity is substantially parallel to the central axis of the loop-gap resonator inside the microwave resonance cavity 17 shown in Fig. 1, it becomes possible, as shown in Fig. 8, to concentrate the peripheral magnetic flux inside the loop-gap resonator, and thus to significantly improve startability of the light source and efficiency of the discharge.

[0033] In addition, although in the above modifications only mercury and argon were mentioned as fillers of the discharge tube, it is understood that that the invention is not limited only to such fillers and that without deviation from the scope of the claims, other additives such as metal halides, or the like, can be used. For example, in Kokai H6-132018 it was proposed to use sulfur as a discharge substance.

[0034]
(Practical Example 2)
The second practical example of the invention will now be described with reference to Fig. 2. The microwave discharge light source shown in Fig. 2 consists of a magnetron 23 that constitutes a microwave generation part, a waveguide 24 that incorporates a microwave propagation function, a power supply port 25, a reflection plate 26, a discharge tube 21, and a loop-gap resonator 22 that is made of a conductive material and constitutes a resonation unit. In this example, a microwave resonant cavity is removed from the device of the first example shown in Fig. 1, and only the loop-gap resonator that incorporates the resonance function is used instead. The modification shown in Fig. 2 makes it possible to miniaturize the part of the previously described microwave resonance function unit that starts from the power supply unit. In other words, the size of the microwave resonance cavity can be reduced from several tens of centimeters to several centimeters.

[0035] A discharge tube 21 and a loop-gap resonator 22 shown in Fig. 2 may structurally be the same as similar devices of the four modifications previously described with regard to the first example and shown in Figs. 3 to 6. In the aforementioned structure of the discharge tube and the loop-gap resonator, the part of the microwave discharge light source that carries the microwave resonance function is miniaturized by arranging the direction of magnetic flux of the microwave electromagnetic field near the power supply port substantially parallel to the central axis of the aforementioned loop-gap resonator.

[0036] The first and second examples of the invention do not specify the method of attaching the loop-gap resonator and the discharge tube, but it may be recommended to use a material that possesses dielectric properties, has low thermal conductivity, and is sufficiently strong. For example, quartz tubes or dielectric ceramics can be used for the above purpose.

[0037]
[Effects of the Invention]
The effects of the invention consist of improved startability of the discharge tube, decreased loss of microwave energy, improved light-emitting efficiency relative to the supplied electric power, and reduced consumption of electric power required for driving

the device. This is achieved by providing a resonator that combines in one conductive member a part that holds the electrically conductive properties in the vicinity of the discharge tube inside one microwave resonance cavity and a part that has a capacitive function.

[0038] Moreover, by combining in a single conductive member the functional part with electrical inductive properties and the part that holds the electric capacitive properties instead of the [conventional] microwave resonant cavity, it becomes possible to miniaturize the aforementioned resonance function part used for driving the discharge tube and to reduce the space between the components of the device.

[Brief Description of the Drawings]

Fig. 1 is a sectional view of the essential parts of the microwave discharge light source according to the first modification of the invention.

Fig. 2 is a sectional view of the essential parts of the microwave discharge light source according to the second modification of the invention.

Fig. 3 is a three-dimensional view of the first modification of the structure composed of a discharge tube and a loop-gap resonator according to the present invention.

Fig. 4 is a three-dimensional view of the second modification of the structure composed of a discharge tube and a loop-gap resonator according to the present invention.

Fig. 5 is a three-dimensional view of the third modification of the structure composed of a discharge tube and a loop-gap resonator according to the present invention.

Fig. 6 is a three-dimensional view of the fourth modification of the structure composed of a discharge tube and a loop-gap resonator according to the present invention.

Fig. 7(a) is a cross-section of the loop-gap resonator.

Fig. 7(b) is a three-dimensional view of the loop-gap resonator.

Fig. 7(c) is an equivalent circuit of the loop-gap resonator.

Fig. 8(a) is a three-dimensional view that illustrates distribution of the magnetic field inside the microwave resonance cavity of TE_{102} mode.

Fig. 8(b) is a three-dimensional view that illustrates distribution of the magnetic field inside the microwave resonance cavity of TE_{102} mode equipped with the loop-gap resonator.

Fig. 9 is a sectional view that illustrates the structure of a known microwave discharge light source.

[Reference Numerals Used in the Specification]

11, 21, 31, 41, 51, 61 - discharge tubes
12, 22, 32, 42, 52, 62, 63, 81 - loop-gap resonators

17, 82a, 82b - microwave resonance cavities
13 23 - magnetrons
14 24 - waveguide
15 25 - power supply ports

Fig. 1

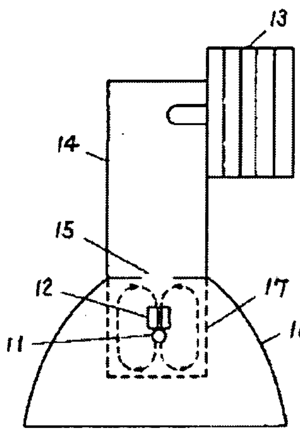


Fig. 2

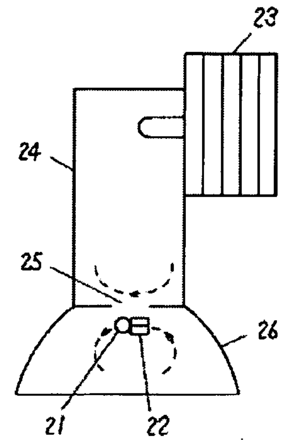


Fig. 3

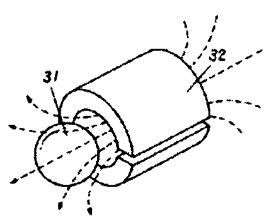


Fig. 4

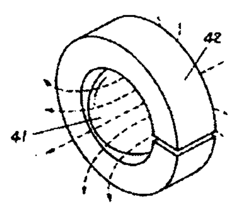


Fig. 5

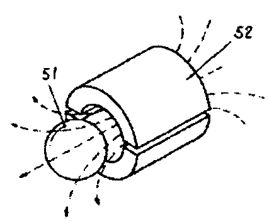


Fig. 6

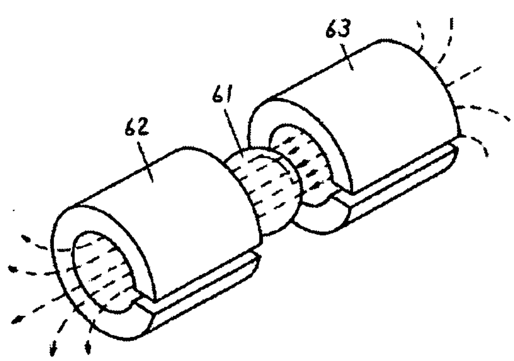
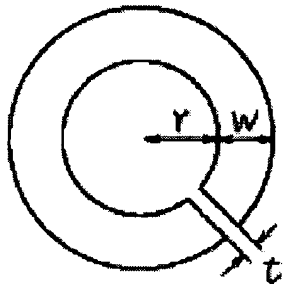
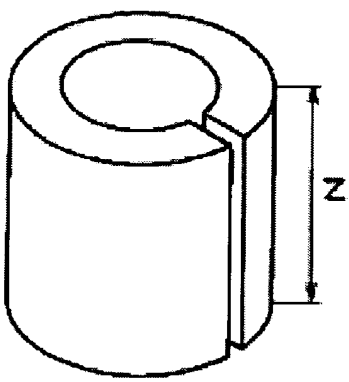


Fig. 7

(a)



(b)



(c)

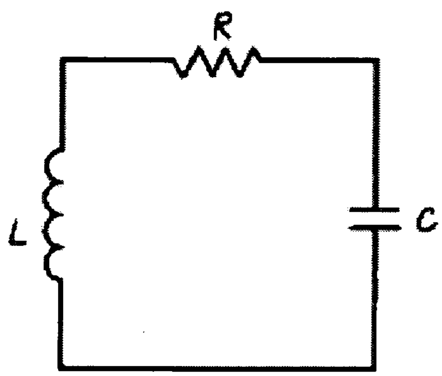


Fig. 8

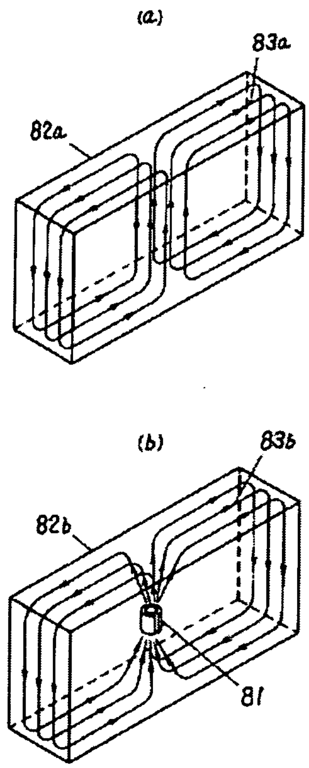
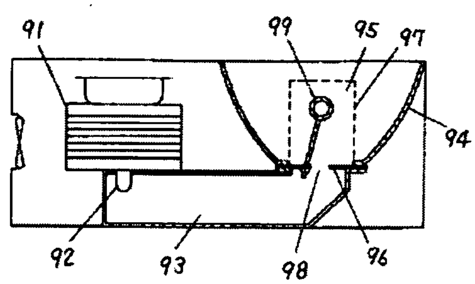


Fig. 9



CERTIFICATION

I, Alexander Shkolnik, an active member of the Japanese Language Chapter of the American Translators Association, hereby certify that to the best of my knowledge and belief, the above is a true, correct, accurate and complete English language translation of the attached Japanese language document. (Japanese Unexamined Patent Application Publication (Kokai) No. **H08-148127)**

San Carlos, CA
July 12, 2006

Alexander Shkolnik